Table 4-1: Clear Air Earth-to-Space Atmospheric Loss vs. Elevation Angle

Rain-Climatic Zone 1		Rain-Climatic Zone 2		Rain-Climatic Zone 3-5	
El. Angle	Atmos.Attn.	El. Angle	Atmos.Attn.	El. Angle	Atmos.Attn.
deg.	dB	deg.	dB	deg.	dB
0.0	19.1	0.0	11.0	0.0	6.8
0.5	13.5	0.5	8.0	0.5	5.1
1.5	8.2	1.5	5.0	1.5	3.3
2.6	5.6	2.6	3.5	2.6	2.4
3.7	4.2	3.7	2.6	3.7	1.8
4.9	3.2	4.9	2.1	4.9	1.4
6.1	2.7	6.1	1.7	6.1	1.2
7.4	2.2	7.4	1.4	7.4	1.0
8.8	1.9	8.8	1.2	8.8	0.8
10.2	1.6	10.2	1.1	10.2	0.7
11.8	1.4	11.8	0.9	11.8	0.6
13.4	1.3	13.4	0.8	13.4	0.6
25.0	0.7	25.0	0.4	25.0	0.3
30.0	0.6	30.0	0.4	30.0	0.3
45.0	0.4	45.0	0.3	45.0	0.2
60.0	0.3	60.0	0.2	60.0	0.2
75.0	0.3	75.0	0.2	75.0	0.1
90.0	0.3	90.0	0.2	90.0	0.1

This table is based on information developed in CCIR Report 719.

b. Scattering effects

The JTSG examined various models that could be employed to determine the scattered energy from a downward pointed hub antenna up into the satellite. The difficulty is that there are no satisfactory models of the scattering coefficients for an urban or suburban environment. It was concluded that this factor could not reliably be included in interference analysis as there are no quantitative factors that had any confidence level attached to them.

c. Polarization Discrimination

Non-GSO MSS satellites will most always employ circular polarization and LMDS systems linear. The question was, under what circumstances should a 3 dB cross polarization isolation be assumed. It is generally well known that circularly polarized antennas only maintain good axial ratios over their half power beamwidths. Therefore, at most, this 3 dB should be included within the satellite's main beam for assessment of Non-GSO MSS feeder link interference into LMDS receivers. For assessment of LMDS interference into Non-GSO MSS satellite uplink receivers, it was assumed that LMDS employs linear polarization and that the satellite uplink receiver employs circular polarization. Consequently, the assumed polarization discrimination of the satellite receiver antenna against LMDS interference is 3 dB.

d. Aggregate Interference Power

The satellite footprint could encompass many simultaneous co-frequency emitters using a wide variety of different modulations. The question is how to sum these individual interferers into the satellite interference. The Working Group examined simulation results that suggest that when the number of sources exceeds 5 and are non coherent, then their effect on the receiver is the same as additive white gaussian noise (AWGN) -- no matter what the relative modulation formats or bandwidths. Therefore, simply summing the up link interfering powers and adding the sum to the satellite thermal noise floor was considered appropriate.

Interference from an earth station into a LMDS receiver is from a single source and may not have the same effect as AWGN. Relative modulation bandwidths and modulation types should be considered.

4.3 Methods of Calculating Interference From LMDS Into Non-GSO MSS Feeder Link Satellite Receivers

a. Aggregate Uplink interference From LMDS Hubs

The FCC submitted a extensive interference study (NRMC-21) that included a model for calculating the aggregate LMDS hub interference into a satellite receiver. This model used a FORTRAN program to calculate interference power level (I_i) from every hub within the forward field of view of the satellite out to the earth's horizon as seen from the satellite. It was assumed that co-frequency hubs are distributed uniformly throughout the satellite's field of view and that the hub's antenna pattern was omnidirectional in azimuth.

In the model, the satellite beam boresight is centered on an earth station operating at a low elevation angle. The satellite half-power beam width is a variable input parameter but peak gain of 30.1 dB is a constant that is built into the program. The up link earth station carrier power (C) could then be calculated from the earth terminal characteristics and combined with the aggregate interference power (I) to calculate C/I. Precise models of both the satellite and hub antennas were used but no allocation for atmospheric loss was made. Essentially the C/I_i due to thousands of hubs were computed and summed for a composite C/I.

Subsequently, two changes to the simulation model were recommended and the source codes modified by Motorola and attached in Attachment C. First, the atmospheric loss vs. elevation angle was incorporated using the CCIR Report 719-3 for each of the 5 climatic zones. Climate zone is now a variable parameter. Second, the output of the program is now Io/No when given the input noise temperature of the satellite. The basic algorithm for this program is:

$$I_o = \sum_{i=1}^{N} I_i$$

where:

$I_i = EIRP_i + L + G_s(\alpha) + XPD + L_a(\alpha)$
$EIRP_i = G_h(\alpha) + spd$
α = *elevation angle of hub above horizon*
$G_s(\alpha)$ = *satellite gain along vector toward hub*
$G_h(\alpha)$ = *hub gain along vector toward satellite*
spd = xmtr spectral power density (watts/Hz)
L = free space loss from hub to satellite
$L_a(\alpha)$ = *atmospheric loss*
$N_o = -228.6 + 10\log T_s$ *(dBW/Hz)*
T_s = *noise temperature satellite °K*
XPD = cross polarization discrimination

In addition, Motorola provided an Excel program dubbed "Quick Look," which made a number of simplifying assumptions so that sensitivity studies of interference parameters could easily be made and synthesis of hub antenna gain above the horizon could be examined closely. One major simplifying assumption was that only hubs within the half power beam width of the satellite footprint were considered. The half power footprint was further simplified by breaking it into 11 equal sized swaths of 110 km by 200 km. These 11 swaths approximate the size of a footprint when operating to an earth station at a 10° elevation angle. The satellite gain was considered constant over the footprint and equal to 1.5 dB less than at peak. This model was also modified to include atmospheric loss depending on in which of the 5 climatic zones the hubs were located. As to be expected, this program predicted 1 to 2 dB less interference than the more exact FORTRAN program does. Attachment D provides a detailed explanation of the spreadsheet design and associated geometries of a footprint. A sample run is shown below in Table 4-2. The table lists only the first 9 swaths used in the run but the composite Io/No from all 11 was equal to -12.8 dB for a hub uniformly spacing of every 7.75 miles throughout the footprint. The satellite receiver characteristics of the Iridium system and hub characteristics of Suite 12 were used for these sample calculations. As can be seen, the spreadsheet also calculates the percent total interference for each swath indicating the interference sensitivity to hub antenna roll off in elevation plane.

Table 4-2: Sample of "Quick Look" Spread Sheet

mid swath elevation	**0.5**	**1.5**	**2.6**	**3.7**	**4.9**	**6.1**	**7.4**	**8.8**	**10.2**
nadir angle (°)	63.0	62.9	62.8	62.7	62.5	62.3	62.0	61.7	61.2
interior angle (°)	26.5	25.5	24.5	23.5	22.5	21.5	20.5	19.5	18.5
latitude angle (°)	63.5	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5
slant range (km)	3194	3082	2971	2860	2749	2638	2528	2417	2308
hub xmit power(dBW/Hz)	-71.9	-71.9	-71.9	-71.9	-71.9	-71.9	-71.9	-71.9	-71.9
hub xmit gain (dBi)	10.0	8.1	6.0	2.0	-1.0	-7.0	-10.0	-10.0	-10.0
path loss (dB)	191.8								
atmosph loss (dB)	-8.0	-5.0	-3.5	-2.6	-2.1	-1.7	-1.4	-1.2	-1.1
antenna polarization	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
satellite receive gain	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
no. of hubs in each	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
recvd power	217.6								
percent total interference	18.6	25.7	24.1	12.7	7.7	2.3	1.4	1.6	1.7

b. Aggregate Uplink Interference From Subscriber Units

Subscriber units can be located several miles from a hub or down at the base of the hub tower. If return links (subscriber to hub) were employed, the elevation angles of the subscriber units would range from 0° to near 90° above the horizon with half-power beam widths from 1 to 5 degrees. The operator would also probably implement some type of power control such that closer in subscriber units had lower gain antennas and/or lower transmitter powers. It is difficult to estimate how many subscriber units an LMDS operator could have operating co-frequency simultaneously back into a single hub. It would depend on the operator's strategy for sectoring the hub receive antennas. The greater the number of sectors, the more simultaneous co-frequency subscriber units would be possible. Therefore, to model the aggregate interference from subscribers, one would have to make assumptions about:

•elevation angle vs. distance from hub antenna heights
•EIRP vs. distance from hub for various climatic zones

•statistical geographic distribution in azimuth from hubs
•statistical geographic distribution in distance from hubs
•number of co-frequency subscribers per hub
•spectral power density of return links vs. different modulation
•duty factor of traffic vs. time of day

This large number of assumptions would make a valid model complex. No such simulation model was developed in Working Group 2.

c. Uplink Interference From Single High Power Backbone Emitter

LMDS backbone links are likely to resemble conventional point-to-point service with relatively high gain narrow beam antennas but high EIRPs would be required to provide high availability under rain fade conditions. LMDS backbone links are more likely to use adaptive power control to overcome rain fades.

It was estimated there would not be many more backbone link T/Rs than hub sites to avoid degrading S/N before delivery to subscriber. From the perspective of the large satellite footprint covering many operators or operators with large service areas then it can be assumed that the backbone links would be randomly scattered in azimuthal direction with most backbone link transmitter antennas pointing within a few degrees of the horizon. It is therefore reasonable to assume that it is statistically unlikely that no more than <u>one</u> high power station at a time would be pointing its antenna above the horizon on an azimuth track back towards the earth station at the proper separation distance from the station to intercept a spot beam from the satellite. Therefore a simple modification was made to the "Quick Look" Excel program to calculate the Io/No from a single station at various elevation angles into a satellite spot beam. The modification simply consisted of putting a single emitter in each swath that is closely aligned in the direction of the gateway and elevated at just the right angle to intercept the footprint of the satellite. A sample calculation is shown in Table 4-3. The table was excerpted from Attachment E. Here the antenna gain was assumed to be 42 dBi, as provided by Suite 12 in its table of characteristics. The reduction in satellite link margin is equal to (Io+No)/No (dB) where No is satellite thermal noise floor.

Table 4-3: UpLink Interference From Single Backbone LMDS Station

emitter elevation angle (°)	**0.5**	**2.6**	**4.9**	**7.4**	**10.2**
nadir angle (°)	63.0	62.9	62.6	62.1	61.3
interior angle (°)	26.5	24.5	22.5	20.5	18.5
latitude angle (°)	63.5	65.5	67.5	69.5	71.5
slant range (km)	3193	2971	2749	2527	2307
xmit power(dBW/Hz)	-77.9	-77.9	-77.9	-77.9	-77.9
xmit gain (dBi)	42.0	42.0	42.0	42.0	42.0
path loss (dB)	-191.8	-191.2	-190.5	-189.8	-189.0
atmosph loss (dB) Zones 3-5	-5.2	-2.4	-1.5	-1.1	-0.8
antenna polarization loss(dB)	-3.0	-3.0	-3.0	-3.0	-3.0
satellite receive gain (dBi)	28.3	28.8	29.2	29.6	30.0
recvd power density	-207.5	-203.6	-201.6	-200.1	-198.6
Io/No (dB)	-10.1	-6.1	-4.2	-2.6	-1.1
Peak EIRP Density	24.1	24.1	24.1	24.1	24.1
Reduction in Link margin(dB)	**0.4**	**0.9**	**1.4**	**1.9**	**2.5**
Satellite noise floor	-197.5				

There were no models proposed to this NRM proceeding which could evaluate the statistics of an intercept between a single high powered backbone station and a Non-GSO MSS satellite. That is, what is the frequency and duration of these short term interference events when examined over a period of days with a Non-GSO MSS constellation operating to an earth terminal at some fixed geographic location?

4.4 Methods Of Calculating Interference From Non-GSO MSS Feeder Links Into LMDS Receivers

Non-GSO MSS feeder link antennas would normally be moderately elevated or placed in an open area such that tracking of the satellite down to 5° in a 360° arc can be accomplished without blockage. Location is likely at edges of metropolitan areas and could be sited on a hill in order to clear obstructions out at the horizon.

For purposes of this analysis, it was assumed that LMDS hub antennas would be mounted high enough to provide maximum unblocked coverage to their cell subscribers and generally have near maximum gain on horizon. Subscriber units would normally be lower than the hub and pointed up with moderate beam width antennas.

Line of Sight (LOS) interference would be the strongest coupling mode between LMDS receivers and MSS earth stations. Antenna gain along the vector between the LMDS receiving antenna and the earth terminal combined with separation distance and atmospheric loss make up the variable components of the interference calculation as shown below:

$I_i = EIRP_i + L + L_a + G_t + G_r$
$EIRP_t = G_t + spd$
G_t = *earth station gain along vector toward LMDS receiver*
G_r = *LMDS receiver gain along vector toward satellite*
spd = xmtr spectral power density (watts/Hz)
L = free space loss
L_a = *atmospheric loss (dB/km)*

It was agreed that a nominal clear air attenuation (L_a) of 0.1 dB per km would be utilized in all calculations. A sample geometry to establish the vector gains was shown in Figure 3-4.

The technical group established a matrix of LMDS and earth station antenna characteristics and calculated the line of sight isolation required for various combinations. Representative interference calculations between an Iridium earth station and an LMDS receiver located at a hub were performed. In addition, the Working Group looked briefly at the probability of significant over the horizon coupling through tropospheric scatter. The methodology from Appendix 28 of the ITU Rules and Regulations was employed to calculate the potential for short term interference between an Iridium earth station and a LMDS hub. The calculation assumes high coupling can only occur for .01% of time with the earth terminal pointed continuously in the direction of the receiver. Since a earth terminal operating to a Non-GSO MSS satellite is continuously adjusting its azimuth and elevation headings the probability of significant interference is very low. Also, the distances this methodology calculated ranged from 18 to 36 miles which is comparable to LOS and therefore not considered significant at 29 GHz.

SECTION V:

ANALYSES AND DISCUSSION OF SHARING SITUATIONS

5.1 Introduction

Five Non-GSO MSS feeder link satellite systems and three LMDS systems were represented on the Negotiated Rule Making Committee. Information necessary for sharing was presented by the following proponents:

Non-GSO MSS: Iridium, Constellation, Ellipsat, TRW
LMDS : Suite 12, VideoPhone, Texas Instruments

The only complete analysis was done between the Iridium system and the three LMDS systems. This was because the Iridium system is the only Non-GSO MSS system with a mature concept for operation of its MSS feeder links in the band 27.5 to 29.5 GHz. A partial analysis was presented by the Constellation representative versus the Suite 12 LMDS system, which gave indications that sharing was possible. No other analysis was performed by the other Non-GSO MSS satellite system proponents.

To date in the U.S., all proposed Non-GSO MSS systems other than the Iridium system use Code Division Multiple Access (CDMA) and intend to "interference share" the 2.5 GHz downlink service frequency band. Since each of these systems use "transparent" transponders, the uplink feeder link band at 29 GHz would be translated to the 2.5 GHz down link service link frequency band, and add interference to that link.

Table 5-1 summarizes the satellite and LMDS interference analysis that were completed. For the three cases analyzed using the parameters provided, it was found that sharing was possible between Iridium and Suite 12, between Iridium and Texas Instruments, but not between Iridium and VideoPhone.

TABLE 5-1
SATELLITE AND LMDS INTERFERENCE ANALYSES COMPLETED

SATELLITE SYSTEM	SUITE 12	TEXAS INSTRUMENTS	VIDEOPHONE
IRIDIUM	YES	YES	YES
CONSTELLATION	PARTIAL	NO	NO
GLOBALSTAR	NO	NO	NO
ODYSSEY	NO	NO	NO
ELLIPSO	NO	NO	NO

5.2 LMDS Into Non-GSO MSS Feeder Link Satellite Receivers

The following results are presented for each of the three LMDS systems versus the IRIDIUM system. In each case the characteristics of the IRIDIUM® system were as defined in NRMC-29 "20/30 GHz Characteristics of the Iridium Network" dated 8/5/94.

Two simulation programs were used in the analysis of sharing between the systems, one by the FCC and one by Motorola as discussed in some detail in Section IV of this report. The results are about a 1 to 2 dB more optimistic for sharing with the Excel program than with the FCC program, as can be seen with the results in Table 5-2. The table summarizes a number of runs at different elevation angles which were made holding the following parameters constant:

The LEOsat orbital altitude (km)..................................... 780.00
The LEOsat antenna half-power beamwidth (deg)....: 5.00
The LEOsat ant main-lobe shape factor (0.8-3.2)..: .80
The atmospheric-attenuation index (climate; 1-5).: 2
The LMDS hub e.i.r.p. density (dBWi/xHz).................. -59.90
The LMDS hub ant mainbeam depression angle (deg).: 1.00
The LMDS hub ant pattern shape factor (0.0, 1.).: 2.00
The LMDS hub antenna main-lobe null angle (deg)..: 10.00
The LMDS hub antenna sidelobe attenuation (dB)...: 5.00
The LMDS co-frequency inter-hub spacing (km)....: 30.00
The polarization attenuation at LEO of LMDS(dB)..: 3.00
The LEO receiver has Tsys=1295.4 xK and No= -197.48dBW/Hz

The hub antenna characteristics and spectral power density are similar to the table of characteristics for a Suite 12 hub video link. For this case the Io/No was calculated for various elevation angles of the footprint satellite antenna beam boresight. The results are summarized below:

TABLE 5-2
SATELLITE UPLINK INTERFERENCE VS. SATELLITE SPOT BEAM ELEVATION ANGLE

Elevation Angle (deg)	Io/No (dB)
5.0	-10.8
10.0	-11.6
12.5	-12.9
15.0	-14.9

It should be noted that the Excel "Quick Look" program calculates an Io/No of -12.8 dB at 10 degrees for this hub spacing and power input to hub antenna used in Table 5-2. However, the subsequent sharing analysis was completed for all systems only using the Quick Look program at 10° for the 3 basic climate zones.

a. Suite 12 Versus IRIDIUM

The analysis was completed using the Suite 12 characteristics presented on August 10, 1994. Attachment F contains the spreadsheets for the analysis considered.

Hub to Satellite

The results of the analysis are shown in Table 5-3. The sharing margin is the difference in aggregate Io/No versus the Iridium required protection criteria of I/No of -13 dB. The Table also calculates the allowable average hub spacing in a service area that would keep the aggregate up link interference within Iridium's budget. Suite 12 indicated that their projected hub spacing in populated areas would be about 6.0 miles and from the table it can be noted that any LMDS operator in Zone 1 could build out 93.7% of its service area with this spacing.

TABLE 5-3
SHARING MARGIN VS CLIMATE REGION
BETWEEN IRIDIUM AND SUITE 12

Zone	SHARING MARGIN (dB)	ALLOWABLE HUB AVG. SPACING (MI)	PERCENT COVERAGE (%)
1	+7.5	6.2	93.7
2	+5	7.75	60.0
3,4,5	+3.6	9.3	41.6

The above margins were calculated assuming the hubs were transmitting a video channel which has the highest spectral power density for the different point to multipoint modulations listed. These margins can be utilized to increase the number of hubs in the more highly populated service areas or add on new services that require higher transmitter powers. Sharing with transmissions from hubs in the Suite 12 type of system and an Iridium type of receiving system is quite practical allowing both systems to achieve their service objectives. Hub density can also be much greater if digital links from the hubs are considered as their spectral power density is several dB less than the FM video.

Backbone to Satellite

It is assumed that there will be about one backbone transmitting station per hub, with the hub density proposed by Suite 12. It is also assumed that very few of those backbone stations will be pointing above the horizon. In addition, the backbone antennas will be relatively narrow beam (on the order of 1°) and relatively randomly oriented in azimuth within the total satellite footprint. Therefore, only an occasional main beam backbone to satellite spot beam coupling will occur. Table 5-4 was constructed using EIRP figures provided by Suite 12.

TABLE 5-4
UPLINK INTERFERENCE POWER VS
ELEVATION ANGLE OF A BACKBONE TRANSMITTING STATION

emitter elevation angle (°)	0.5	2.6	4.9	7.4	10.2	12.7
slant range (km)	3194	3082	2971	2860	2749	2638
xmit power (dBW/Hz)	-77.9	-77.9	-77.9	-77.9	-77.9	-77.9
xmit gain (dBi)	42.0	42.0	42.0	42.0	42.0	42.0
path loss (dB)	-191.8	-191.5	-191.2	-190.8	-190.5	-190.1
atmosp loss (dB) Zones 3-5	-5.2	-3.4	-2.4	-1.9	-1.5	-1.2
antenna polarization loss(dB)	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
satellite receive gain (dBi)	28.3	28.6	28.8	29.0	29.2	29.4
received power density (dBW/Hz)	-207.5	-205.1	-203.6	-202.6	-201.6	-200.8
received power density (W/Hz)	1.8E-21	3.1E-21	4.4E-21	5.5E-21	6.9E-21	8.4E-21
Io/No (dB)	-10.1	-7.7	-6.1	-5.1	-4.2	-3.3
peak EIRP Density (dBW/MHz)	24.1	24.1	24.1	24.1	24.1	24.1
Reduction in Link Margin (dB)	0.4	0.7	0.2	1.2	1.4	1.7

While significant interference power is received by the satellite from a mainbeam coupling with a single backbone transmitter, the likelihood of two or more mainbeam couplings occurring simultaneously is low. Motorola therefore considered that it was permissible to exceed the interference budget of Io/No = -13 dB by 10 dB for these short term events with out significantly affecting the Iridium link availability. Sharing a common frequency band between a Suite 12 type backbone transmitter and an Iridium type receiving spot beam is considered quite possible with some acceptable risk if the peak EIRP density from a backbone is restricted to 23 dBW/MHz used in this analysis.

Subscriber to Satellite

As discussed in Section IV, the Working Group was not able to develop an accurate generic model of the number and types of co-frequency transmissions from subscribers back to the hub. Co-frequency sharing of Suite 12 subscriber transmissions with Iridium satellite receivers could not be determined, and thus does not appear to be feasible. Suite 12 indicated that it never anticipated the return traffic from subscribers to exceed the traffic out to subscribers from the hubs. Even with no return links in up to 400 MHz, adequate capacity is still available for Suite 12's return traffic.

b. TI Versus IRIDIUM

This analysis considers only the Hub to Satellite interference cases. The TI system did not define a "backbone" as part of their system. The "Quick Look" was again used for this analysis, with the results shown in Table 5-5 and detailed calculations contained in Attachment G.

Hub to Satellite

The results of the analysis are shown in Table 5-5.

TABLE 5-5
SHARING MARGINS BETWEEN IRIDIUM AND TI

Zone	System 1 Wideband dB	System 2 Narrowband dB	System 3 FM dB	System 4 AM dB
1	11.1	11.1	7.9	3.1
2	10.7	10.7	5.5	1.1
3,4,5	9.5	9.5	4.3	-0.5

The inputs to the analysis program were as follows:

Transmitter spectral density/Hub (dBW/Hz):

System 1 (wideband digital): - 89.8 dBW/Hz
System 2 (narrowband digital): - 89.8 dBW/Hz
System 3 (FM): - 84.6 dBW/Hz
System 4 (AM): - 79.8 dBW/Hz

Maximum number of Hubs in a 200 km X 110 km "swath": 164

Number of Hubs in the satellite footprint (11 swaths): 890

Frequency Reuse: 1/1

Peak Antenna Gain: 15 dB

Antenna Pattern: As defined in Table of Characteristics from TI

The conclusions that may be drawn from the table are that the systems may co-frequency share in the Hub to Satellite direction. In all but one case (AM) there is ample margin for adjusting service requirements.

Subscriber to Satellite

It was assumed that co-frequency sharing between the Iridium satellite receivers and the TI subscriber unit transmitters was not feasible. Like Suite 12, TI did not indicate a need for a channel plan with more than return bandwidth than forward bandwidth. TI also indicated that even with no return links in up to 400 MHz, adequate capacity is available for TI's return traffic.

c. VideoPhone Versus IRIDIUM

This analysis considers only the Hub to Satellite and Subscriber to Satellite interference cases. The VideoPhone system specification did not provide parameters for a "backbone" operation. VideoPhone did provide parameters for a high power density, high data return link. Detailed calculations of uplink inteference from VideoPhone hubs is contained in Attachment H.

Hub to Satellite

The results of the analysis are shown in Table 5-6.

TABLE 5-6
SHARING MARGINS BETWEEN IRIDIUM AND VIDEOPHONE

Zone	Digital dB	FM dB	AM dB
1	-21.9	-21.6	-21.9
2	-25.3	-25.0	-25.3
3,4,5	-27.1	-26.8	-27.1

The inputs to the analysis program were as follows:

Transmitter spectral density/Hub (dBW/Hz):

Digital: - 83.6 dBW/Hz

FM: - 83.9 dBW/Hz

AM: - 83.6 dBW/Hz

Maximum number of Hubs in a 200 km X 110 km "swath": 8360

Frequency Reuse: 1/1 (worst case)

Peak Antenna Gain: 29.7 dB

The table shows that the margins are negative. Based solely on the negative margins, there is no possibility of co-frequency sharing. These large negative margins are due to the extreme density of hubs within the satellite's footprint and the large EIRP power transmissions from the hubs out towards the horizon.

Subscriber to Satellite

The number of subscriber units would be quite high to support the hub density so it is anticipated that this large number of units with their antennas pointed above the horizon would create unacceptable interference to an Iridium-like satellite. Based on the assumptions used in the analysis included in Attachment I, co-frequency sharing of VideoPhone subscriber transmitters with Iridium satellite receivers in these bands is not considered possible.

5.3 Non-GSO MSS Feeder Link Earth Stations Into LMDS Receivers

Attachment J contains a wide combination of scenarios relative to an Iridium satellite potentially interfering with a LMDS receiver. The Iridium earth terminal is designed to begin acquisition of the satellite when the antenna is pointed 5 degrees above the horizon in order to be fully connected at 10 degrees. An earth station antenna site would, for some time on each pass, be pointing at two Iridium satellites simultaneously. Generally, if the LMDS subscriber receiver or hub receiver should be pointed in the direction of the Iridium feeder link earth station antenna, then unacceptable interference would occur unless the LMDS receiver was over the radio horizon from the earth station antenna site. If the LMDS subscriber antenna is pointed away from the Iridium earth station by 5° or more, then the LMDS receiver can be within a few tens of kilometers of the Iridium earth station without receiving unacceptable interference.

This section of the report describes the calculations of interference from Mobile Satellite Service (MSS) Feeder Links into Local Multipoint Distribution Services (LMDS) receivers. Both hub and subscriber receivers are considered for LMDS systems characteristics provided by Suite 12/CellularVision, Video/Phone, and Texas Instruments. Interference is generated by an IRIDIUM™ feeder link earth station. Calculations for the LMDS system signal path assume a subscriber at the edge of the coverage area. (See Attachment J for the results.)

Three different radio paths are considered in this interference analysis. Both the LMDS and MSS feeder link systems have a desired transmission path. In addition, there is an interference path between the MSS transmitter into an LMDS receiver. With rain/no rain conditions on each path, there are a maximum of eight possible rain conditions that could occur. The maximum number of conditions has been reduced to the following four cases:

1. LMDS desired signal in clear sky
   MSS desired signal in clear sky
   Interference path between systems in clear sky
   This case is the most probable propagation condition.
2. LMDS desired signal in clear sky
   MSS desired signal in clear sky
   Interference path between systems in 21 mm/hr rain condition (up to 4 km maximum rain cell size)
   This case illustrates the impact of rain on reducing the required separation distance to avoid interference.
3. LMDS desired signal in rain (amount of attenuation as specified by system proponent)
   MSS desired signal in 15 dB rain attenuation
   Interference path between systems in clear sky
   This case is believed to be the worst case interference scenario since the MSS system employs power control to increase transmitter power under rain faded conditions, and LMDS systems may or may not employ power control during rain-faded conditions. In the absence of rain on the interference path, the required separation distances are largest.
4. LMDS desired signal in rain (amount of attenuation as specified by system proponent)
   MSS desired signal in 15 dB rain attenuation
   Interference path between systems in 21 mm/hr rain condition (up to 4 km maximum rain cell size)
   This case represents a more likely rain condition than condition 3 mentioned above.

Calculations are performed for four MSS earth station antenna angles from boresight where that angle can encompass both azimuth and elevation differences. Four LMDS antenna azimuth angles are considered for angles relative to the boresight pointing directly at the earth station. These angles are 5, 10, 20, and 48 degrees off boresight for the earth station (ES) antenna, and 0, 5, 45, and 180 degrees for the LMDS antenna azimuth. The ES angles are selected for the minimum elevation angle of 5 degrees (azimuth aligned with victim receiver) up to a maximum of 48 degrees, beyond which the ES antenna pattern mask is constant. LMDS azimuth angles are selected for boresight (worst case), 5 degrees off boresight, 45 degree sidelobes, and the 180 degree backlobe. The non-boresight angles are calculated in order to examine the impact of LMDS receiver antenna pointing on the required separation distance/margin to avoid interference.

For each combination of ES antenna angle from boresight, LMDS receiver antenna azimuth angle, and rain on the MSS and LMDS desired signal links, the results are presented in several different ways. First, the margin in decibels is calculated under clear sky interference conditions for a 1 km separation between the interference source and LMDS receiver. The required separation under clear sky is calculated based on free space path loss vs. distance plus a 0.1 dB/km atmosphere induced attenuation. Next, the margin in decibels is calculated under a 21 mm/hr rain rate along a 1 km interference path. The rain attenuation along the interference path is calculated using the Lin model for terrestrial rain attenuation. The required separation is then calculated based on free space path loss vs. distance plus a 0.1 dB/km atmosphere induced attenuation and rain attenuation. The rain attenuation is calculated using the Lin model for a rain rate of 21 mm/hr over a maximum rain cell size of 4 km. For each minimum required separation, the allocation of path loss to free space, atmosphere, and rain attenuation are presented in the spreadsheet.

5.3 Spreadsheet Organization and Calculation Assumptions

The spreadsheet (see Attachment J) describing the calculations is arranged by columns to identify the LMDS system being interfered with. For a given set of system parameters, calculations span four columns. Two sets of system parameters are displayed on a page. Rows 1-180 are used to step through the interference calculations. Each set of calculations spans five pages.

a. LMDS System Parameters and Feeder Link System

Lines 1 through 13 are used as column headings for each of the five pages for a set of calculations. These lines list the LMDS and MSS system designs considered in the interference analysis for each set of four columns. System proponent, link (hub-to-sub or sub-to-hub), modulation, digital data rate, channel bandwidth, antenna pattern used, and date/revision of system parameters are listed in this section on lines 4-10. Line 12 indicates the MSS feeder link system under consideration. All calculations are performed for an IRIDIUM™ MSS feeder link.

b. Required Separation

Lines 14-20 summarize the clear sky separations required to reduce interference to acceptable levels for the different combinations of ES angle off boresight and LMDS receiver antenna azimuth angle. All separation distances are reduced to a maximum of 100 km to incorporate a conservative estimate of the radio horizon distance. Beyond the radio horizon, it is assumed that interference is reduced to acceptable levels. The calculations are based on a flat earth propagation model where the terminals are located at the same elevation above ground level.

c. Calculations:

1. LMDS Signal Link Carrier Level at Cell Edge

Lines 24-33 describe the characteristics of the LMDS signal link for a subscriber located at a distance equal to the cell edge. Values are taken from the Signal Parameters List which is denoted document WG 1/52 (rev. 4) dated 9/20/94. When LMDS systems employ power control to overcome rain fades, the amount of power control used in the calculations is the minimum necessary to compensate for the rain fade. For lines 24-33, the first column in the set of four columns for a given system denotes the clear sky link budget, and the third column denotes the link budget under rain conditions.

> Note: Due to a misunderstanding, the Suite 12 Subscriber-to-Hub links indicate use of power control. This is not the case, and no conclusions should be based upon the calculations performed for these particular links. The calculations are for a required C/(N+I) of 19 dB in both clear sky and rain faded conditions with power control to overcome the rain fades. The appropriate analysis is for a required C/(N+I) of 15 dB under both clear sky and rain faded conditions with no power control.

2. Interference Density into LMDS

Lines 40-51 are used to calculate the interference density that can be tolerated by the LMDS system receiver. The calculation starts by computing the noise floor of the LMDS receiver. Based on the minimum required C/(N+I) and the carrier level at the cell edge (C), the maximum acceptable interference in a single channel is calculated on line 49. This value is converted to an interference density (dBW/Hz) in line 50 by dividing by the channel bandwidth.

3. Interference Density Generated

Lines 57-71 describe the MSS feeder link from the ES to the satellite as a function of off boresight angle. The four columns under the calculations for each LMDS system describe how the parameters vary as a function of the off boresight angle given on line 57. The 10 degree off boresight case was used as a baseline with variations in slant path length and the associated slant path power control to compensate for atmospheric attenuation. The interference density subtotal for clear sky conditions is given on line 65. Lines 66-69 are used to describe the link conditions under rain. Lines 66-68 are not used, and should be ignored. Line 69 indicates that the feeder link system undergoes a 15 dB rain fade. The power control required to overcome the rain fade is also 15 dB as described in line 70. The total power control available to overcome slant path and rain attenuation is limited to 24.8 dB for the IRIDIUM™ system which uses power control to maintain a nearly constant Eb/No at the satellite receiver. Antenna gains are based on the ITU-699 antenna mask of 32-25*log(theta). The interference density subtotal is calculated based on an additive white gaussian noise (AWGN) assumption for interference density when a narrow band interferer interferes with a wider bandwidth signal. This may slightly underestimate the effect of the amount of interference at the victim receiver. The interference density subtotals on lines 65 and 71 are the transmitted interference density subtotals before any propagation path loss is included.

4. LMDS Receiver Antenna Gain

Lines 87-91 represent the antenna gain of the victim LMDS receiver as supplied by the system proponent for antenna azimuth angles of 0, 5, 45, and 180 degrees off boresight.

5. Results of Calculations

The results of the calculations are provided on lines 95-180. The case of clear sky conditions on both signal paths are detailed on lines 95-136. The columns for the calculations represent the earth station angle off boresight. Calculations for LMDS boresight are given on lines 97-106. These calculations are repeated for the other LMDS antenna azimuth angles on lines 107-136, and the components of the calculations are identical to the boresight antenna calculations described below.

Line 98 is the path loss required to reduce the interference to an acceptable level.

Line 99 presents the margin between the actual interference density and the maximum acceptable interference density at the LMDS receiver for an interference source located 1 km from the victim in clear sky conditions. Line 100 shows the required separation between the terminals for clear sky conditions (free space path loss, atmospheric attenuation) for the required path loss given on line 98. No radio horizon limitations are imposed. Under 21 mm/hr rain conditions, the margin at 1 km separation is given on line 101. Line 102 shows the required separation between the terminals under 21 mm/hr rain rate conditions. A maximum rain cell size of 4 km is used to limit the amount of rain attenuation observed. Lines 103-106 demonstrate the allocation of the path loss for the required separation on line 102. Line 104 is the free space path loss, line 105 is the atmospheric attenuation, and line 106 is the rain attenuation. All path loss values in the spreadsheet represent positive loss regardless of the sign (+/-) of the number in the spreadsheet cell.

Lines 139-180 summarize the calculations for rain conditions on the feeder link and LMDS desired signal paths.

ATTACHMENT A

List of WG2 Participants

Appendix A

LIST OF WORKING GROUP 2 PARTICIPANTS

NAME	**AFFILIATION**
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ATTACHMENT B

Working Group 2 Document List